Three Year Summary Age and Growth Report

For

Sand shiner
(*Notropis stramineus*)

Pallid Sturgeon Population Assessment Project and Associated Fish Community Monitoring for the Missouri River

Prepared for the U.S. Army Corps of Engineers – Northwest Division
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Executive Summary

Pallid sturgeon *Scaphirhynchus albus* are native throughout the Missouri River and the middle and lower Mississippi River. Due to human influences, population levels of this species have greatly declined over the last century. To study this species in-depth, the U.S. Army Corps of Engineers (COE) developed the Pallid Sturgeon Population Assessment Program (PSPAP).

To meet the objectives of the PSPAP, eight species of fish were collected for age and growth analysis as a representative group of native Missouri River fishes. Age-growth information is important to fisheries management because this data can be used to answer many questions and problems that exist within a fishery. Length–at-age information can be used to show trends, either positive or negative, of the condition of a species. When a management strategy is implemented, this information can be used to determine the effectiveness of the plan.

These selected Missouri River fishes were processed by the following PSPAP agencies: Sand Shiner-*Notropis stramineus,* Sauger-*Sander canadensis*, Plains Minnow, Brassy Minnow and Western Silvery Minnow-*Hybognathus spp.* (Missouri Department of Conservation), Sicklefin Chub-*Macrhybopsis meeki*, Speckled Chub-*Macrhybopsis aestivalis, and* Sturgeon Chub-*Macrhybopsis gelida*, (U.S.Fish and Wildilfe Service-Columbia Fisheries Resource Office), Shovelnose Sturgeon-*Scaphirhynchus platorynchus*, (Nebraska Game and Parks Commission) and Blue Sucker-*Cycleptus elongatus* (South Dakota Game, Fish and Parks).

Age structures were taken on sand shiners during fish community season from August - September in 2004 and July - October in 2005 and 2006. Sand shiners were collected using otter trawls, push trawls, beam trawls, bag seines, and mini-fyke nets. During 2004 through 2006 5,116 sand shiners were captured from all segments combined with age structures collected from 390 of these fish. Mean back calculated length at last annulus for the upper universe was 35 mm at age 1. Mean back calculated length at last annulus for the lower universe was 33 mm at age 1 and 49 mm at age 2.

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Introduction

Pallid sturgeon *Scaphirhynchus albus* are native throughout the Missouri River and the middle and lower Mississippi River. Due to human influences, population levels of this species have greatly declined over the last century. Contributions to losses include reduced water quality, habitat loss, barriers to migration and over-fishing. As a result Pallid Sturgeon were listed as endangered by the U.S. Fish & Wildlife Service in 1990 (Drobish 2007b).

The Pallid Sturgeon Recovery Plan (USFWS 1993) identified six priority pallid sturgeon recovery management areas (RPMAs), four of which lie within the Missouri River. Further, this document provided an outline that proposed to: 1) protect and restore pallid sturgeon populations, individuals, and their habitats; 2) conduct research necessary for survival and recovery of pallid sturgeon; 3) develop and implement a pallid sturgeon captive propagation program, and; 4) coordinate and implement conservation and recovery of sturgeon species (Drobish 2007b).

In 2000, the U. S. Fish and Wildlife Service (USFWS) issued the U. S. Army Corps of Engineers (COE) the <u>Biological Opinion on the Operation of the Missouri River Main System Reservoir system Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project and Operation of the Kansas River Reservoir System</u> (Bi-Op). This document recommended that the flow regime of the Missouri River mimic a more natural hydrograph, an increase in propagation and population augmentation efforts, and the development of a pallid sturgeon population assessment program (PSPAP). As the federal entity responsible for water management within the Missouri and Kansas River systems, the COE has an obligation under the Endangered Species Act to conserve the pallid sturgeon. To comply with the Bi-Op, the COE has proposed to operate Gavins Point Dam in a manner to create a more natural hydrograph, has funded hatchery improvements and expansions, has funded the PSPAP, and facilitated the development of the Pallid Sturgeon Population Assessment Team (Drobish 2007b).

The initial stocking of pallid sturgeon in 1994 consisted of approximately 7,000 fish from the 1992 year class that were stocked into RPMAs 4 (Missouri River below Gavins Point Dam) and 5 (middle Mississippi River). Subsequent stockings in 1997, 1998, 2000, and 2002 through 2005 in all six RPMAs have resulted in nearly 172,000 pallid sturgeon being stocked into the Missouri and Mississippi river systems (Drobish 2007b).

Implementation of the PSPAP began in 2001 when the USFWS-Columbia Fishery Resource Office (USFWS-CFRO) began monitoring under PSPAP guidelines and Nebraska Game and Parks Commission (NGPC) conducted an evaluation of benthic trawls. The COE hired a fishery biologist to coordinate the PSPAP in 2002 and the USFWS-CFRO and NGPC continued monitoring in segments 9, 13, and 14 in the lower Missouri River. Standardized sampling above Gavins Point Dam (segments 5 and 6) occurred for the first time in 2003 by the USFWS-Great Plains Fish and Wildlife Management Assistance Office. During 2004, monitoring continued in segments 5, 6, 8, 9, 13, and 14, and an independent science review was conducted to determine the ability of the PSPAP to address its objectives. Beginning with the 2005 fish community season, the Team added the USFWS-Missouri River Fish and Wildlife Management Assistance Office (segment 4), the South Dakota Department of Game Fish and Parks (segment 7), and the Missouri Department of Conservation (segments 10 and 11). In 2006, the team added the Montana Department of Fish, Wildlife, and Parks field crew to complete implementation of the PSPAP from segment 1 through 14 (Drobish 2007b).

The objectives of the PSPAP are as follows: 1) document annual results and long-term trends in pallid sturgeon population abundance and geographic distribution throughout the Missouri River System; 2) document annual results and long-term trends of habitat use of wild pallid sturgeon and hatchery stocked pallid sturgeon by season and life stage; 3) document population structure and dynamics of pallid sturgeon in the Missouri River System; 4) evaluate annual results and long-term trends in native target species population abundance and geographic distribution throughout the Missouri River system; 5) document annual results and long-term trends of habitat usage of the native target species by season and life stage; and 6) document annual results and long-term trends of all non-target species population abundance and geographic distribution throughout the Missouri River system, where sample size is greater than fifty individuals (Drobish 2007b).

To meet objective 5 of the PSPAP, age-growth and relative weight information was collected on a representative group of native Missouri River fishes. These target species were chosen based on possible prey and habitat relationships of pallid sturgeon and those listed as Missouri River species of concern (Berry and Young 2001).

Age-growth and relative weight information is important to fisheries management. These data can be used to answer many questions and problems that exist within a fishery. Length at age information can be used to show trends, either positive or negative, of the condition of a species. When a management strategy is implemented, this information can be used to determine the effectiveness of the plan (DeVries and Frie 1996).

The selected Missouri River fishes were processed by the following PSPAP agencies: Sand Shiner-*Notropis stramineus,* Sauger-*Sander canadensis,* Plains Minnow, Brassy Minnow and Western silvery Minnow-*Hybognathus spp.* (Missouri Department of Conservation), Sicklefin Chub-*Macrhybopsis meeki,* Speckled Chub-*Macrhybopsis aestivalis, and* Sturgeon Chub-*Macrhybopsis gelida,* (USFWS-Columbia Fisheries Resource Office), Shovelnose Sturgeon-*Scaphirhynchus platorynchus,* (Nebraska Game and Parks) and Blue Sucker-*Cycleptus elongatus* (South Dakota Game, Fish and Parks).

Study Area

The Missouri River was divided into segments for the PSPAP based on changes in physical attributes of the river (e.g., tributary influence, geology, turbidity, degrading or aggrading stream bed, etc.) (Figure 1). These segments were numbered 1 through 14 in a downstream direction and included all riverine portions of the Missouri River from Fort Peck Dam to the confluence (Table 1). Segments were also divided into an upper and lower sampling universe based on longitudinal difference as well as the length of the fish's growing season. Segments 1 through 4 make up the "upper sampling universe"; it is characterized by a meandering, often braided channel that lacks navigation structures. Segments 1 through 4 lie in RPMA 2 and includes the 203.5 river miles from Fort Peck Dam downstream to the headwaters of Lake Sakakawea, North Dakota.

Segments 5 through 14 make up the "lower sampling universe"; the lower sampling universe is characterized by having been highly engineered from its original state. Segments 5 and 6, lie in RPMA 3, and consist of 55 river miles from Fort Randall Dam, South Dakota, downstream to the headwaters of Lewis and Clark Lake, Nebraska-South Dakota. Segment 7 extends from Gavins Point Dam downstream 61 miles to Lower Ponca Bend, Nebraska-South Dakota, and is the only segment below Gavins Point Dam that is not channelized.

Segments 8 through 14 of the lower universe include the entire channelized portion (750 miles) of the Missouri River that extends from Lower Ponca Bend to the confluence with the Mississippi River. The Kansas River, from the Johnson County Weir (Kansas) to the mouth (15.4 miles), was given its own segment designation (segment 11) because this tributary was addressed by the 2000 Bi-Op as a high priority management area for pallid sturgeon (Caton et al. 2007).

Methods

All sampling was conducted in accordance with the guidelines established by the Pallid Sturgeon Assessment Team as outlined in the Missouri River Standard Operating Procedures for Sampling and Data Collection (Drobish 2007a) and Pallid Sturgeon Population Assessment Program ,(Drobish 2007b). Two distinct sampling seasons were established to assess sturgeon species and associated fish community. The sturgeon sampling season begins 1 November, or when water temperature drops below 12.8ºC, and continues until 30 June. Gear types used during this season include gill nets, trammel nets, otter trawls, and hoop nets. Fish community season runs from 1 July and continues through 31 October. Gear types used during the fish community season include trammel nets, benthic otter trawls, hoop nets, mini-fyke nets, push trawls, beam trawls, and bag seines.

Sampling Gears

Otter Trawl - Two different benthic otter trawls (OT) were used to sample a variety of river habitats with water greater than 1.2 m in depth: OT16, and OT01. The OT16 and OT01 had a 4.9 m (16 ft.) head-rope and a 0.9 m mouth height. The OT16 was 7.6 m long with size 110 mesh around the cod end. The OT01 was 7.2 m long with 4 mm mesh around the cod end. The towing warp consisted of 13 mm low-stretch nylon line with a 13.7-m bridle. Otter trawls were deployed from the stern or the bow of a jet boat while traveling in a downstream direction. A buoy and line were attached to the cod end of the trawls for retrieval if a snag was encountered. Standard trawl hauls ranged from a minimum distance of 75 m to a maximum distance of 300 m. Standard paired wooden otter doors (762 mm (30 in.) x 381 mm (15 in.)) were used on all otter trawls.

Push Trawl **-** Push trawls (P0T2) were used to sample water between 0.25m and 1.2 m off the bow of a jet boat while traveling in a downstream direction. They were deployed by mechanical means using forward facing outriggers of sufficient length to allow the net to fish ahead of the point where the boat breaks the water. Rope is then let out to accommodate for varying depths. Standard trawl hauls ranged from a minimum distance of 15 m to a maximum distance of 150 m. All push trawls were designed with a 2.4 m (8 ft.) headrope, 0.6 m mouth height, and an overall length of 1.8 m. Paired wooden doors were 762 mm (30 in.) x 381 mm (15 in.).

Beam Trawl **-** Beam trawls (BT) were deployed from the stern or the bow of a jet boat while traveling in a downstream direction. A buoy and line was attached to the crossbar of the trawl frame for retrieval if a snag was encountered. Standard beam trawl hauls ranged from a minimum distance of 75 m (25 m in pools) to a maximum distance of 300 m. Beam trawls were 2 m in width, 0.5 m in height, and 5.5 m in length. The trawl frame consisted of two D-shaped, sled-like runners held apart by a beam to which the net was attached.

Bag Seine **-** Bag seines (BS) were used to sample water less than 1.2 m using three seine haul configurations: quarter arc, half arc, and rectangular. Seining with any method could be conducted in an upstream or downstream direction. Standard seine hauls covered a minimum of 50 m^2 of river bottom. Bag seines were constructed from 6.4 mm ace mesh, were 9.1 m (30 ft.) in length and 1.8 m (6 ft.) in depth. Bag dimensions were 1.8 m x 1.8 m x 1.8 m. Seines were attached at each end to 1.8 m x 51 mm brails (Kennedy et. al 2005).

Mini-fyke Net **-** Mini-fyke nets (MF) were set in shallow, slack water areas with the lead extending perpendicular to the river bank or sand bar. In areas with moderate flow, nets were positioned at a slight downstream angle with weights attached to the upstream side of the cab to prevent the net from overturning. The perpendicular distance measured from the midpoint of the cab to the bank was recorded. Nets were generally set in the afternoon and left overnight with a maximum soak time of 24 hours. Mini-fyke nets were constructed from 3-mm ace or delta mesh with two rectangular frames 1.2 m wide and 0.6 m high to form the cab. The body of the net was constructed with two 0.6 m steel hoops, with a single, 51-mm throat. The lead was 4.5-m in length and 0.6 m high (Kennedy et. al 2005).

Data Collection and Analysis

Sand shiner aging structures were collected from ten fish for each 10 millimeter length class for each segment, species, and year. Aging structures from fish of all size were collected during the fish community season (July 1 –October 31) in all segments, and there was no cut-off for the maximum length of fish from which structures were collected for individuals. The entire fish was preserved in the field, properly identified in the lab, and sent to the Missouri Department of Conservation in Chillicothe, MO for age and growth assessment.

Preserved sand shiners were received by MDC from each field office for age and growth analyses. Each fish was sent in a separate vial labeled with field office, segment, date of capture, unique id, and fish number. Scales were removed from each fish between lateral line and dorsal fin. Scales were cleaned either by hand with a microbrush or in an ultrasonic cleaner as outlined in the Missouri River SOP (Drobish 2007a). Cleaned scales were then placed between two glass slides and labeled with identifying information.

Images from prepared structures were digitally captured using a Paxcam 3 digital microscope camera mounted on an Olympus SZ61TR stereo microscope using Sigmascan 5 software. Structures were recorded on the monitor at a magnification of 106.2X. Captured images were named with all pertinent information in the title, including field office, river segment, unique ID, collection season year, fish identification number, and structure type. They were then saved according to collection season year, species, and segment number.

Two readers independently analyzed each scale, recording annuli number and location. Ages were compared, and any difference in age was discussed, until a concert agreement was reached. Sigmascan was then used to measure the cumulative distance (in pixels) from the focus to each annuli, then to the outer edge. Annuli in scales were determined to be the outermost border of closely spaced circuli before growth resumed in the spring causing circuli to be spaced farther apart and more defined (DeVries and Frie 1996). Annuli formation in sand shiner occurs between late March and June (Fuchs 1967;

Summerfelt and Minckley 1969). Thus, collecting sand shiners from July through October eliminates the concern of collecting age structures when annuli are forming.

The Fraser-Lee method was used in determining back calculated length at age for the sand shiner (DeVries and Frie 1996). For this model a species specific y-intercept is required. A study on the Kansas River related to sand shiner life history (Summerfelt and Minckley 1969) stated a y-intercept of 10.5 mm. However, to more accurately assess the back-calculated length at age, we calculated a y-intercept that was not geographically isolated. A representative sample of 50 randomly selected sand shiners (5 fish per 10 millimeter length group) were chosen for analysis. The prepared scales were viewed under an Olympus SZ61 microscope equipped with a Paxcam 3 digital microscope camera with Sigma Scan 5.0 imaging software. Each scale radius (i.e., the center of the focus to the scale edge) was measured to the nearest hundredth of a millimeter. A linear regression plotting the total length of fish at capture (Y) against the scale radius (X) resulted in line of $y = 37.051x + 11.27$, with an r^2 value of 0.81 (Appendix A). Regression results indicated that scale formation (when $x = 0$) occurred when fish length (y) was estimated at 11.27mm.

All aging data were entered into a Microsoft Excel spreadsheet. Statistical analysis was done using SAS 9.1 and Excel. Data were tested for normality using a Kurtosis test and processed using a parametric ANOVA, Tukey multiple comparison test, linear regression, and t-test. Heincke's method (Isely and Grabowski 2007) was used to calculate annual mortality. SigmaPlot 9.0 was used to construct figures.

Table 1. Description of each segment of the Missouri River with its corresponding river miles.

Segment Number	Segment Description	Upper River Mile	Lower River Mile	Length (mi)
1	Fort Peck Dam to the confluence of the Milk River	1771.5	1760.0	11.5
2	Confluence of the Milk River to Wolf Point	1760.0	1701.0	59.0
3	Wolf Point to the confluence of the Yellowstone River	1701.0	1582.0	119.0
4	Confluence of the Yellowstone River to the headwaters of Lake Sakakawea	1582.0	1568.0	14.0
5	Fort Randall Dam to the confluence of the Niobrara River	880.0	845.0	35.0
6	Confluence of the Niobrara River to the headwaters of Lewis and Clark Lake	845.0	825.0	20.0
7	Gavins Point Dam to Lower Ponca Bend	811.0	750.0	61.0
8	Lower Ponca Bend to the confluence of the Platte River	750.0	595.0	155.0
9	Confluence of the Platte River to the confluence of the Kansas River	595.0	367.5	227.5
10	Confluence of the Kansas River to the confluence of the Grand River	367.5	250.0	117.5
11	Lower Kansas River, Johnson County Weir to mouth	15.4	0	15.4
13	Confluence of the Grand River to the confluence of the Osage River	250.0	130.0	120.0
14	Confluence of the Osage River to the confluence with the Mississippi River	130.0	0.0	130.0

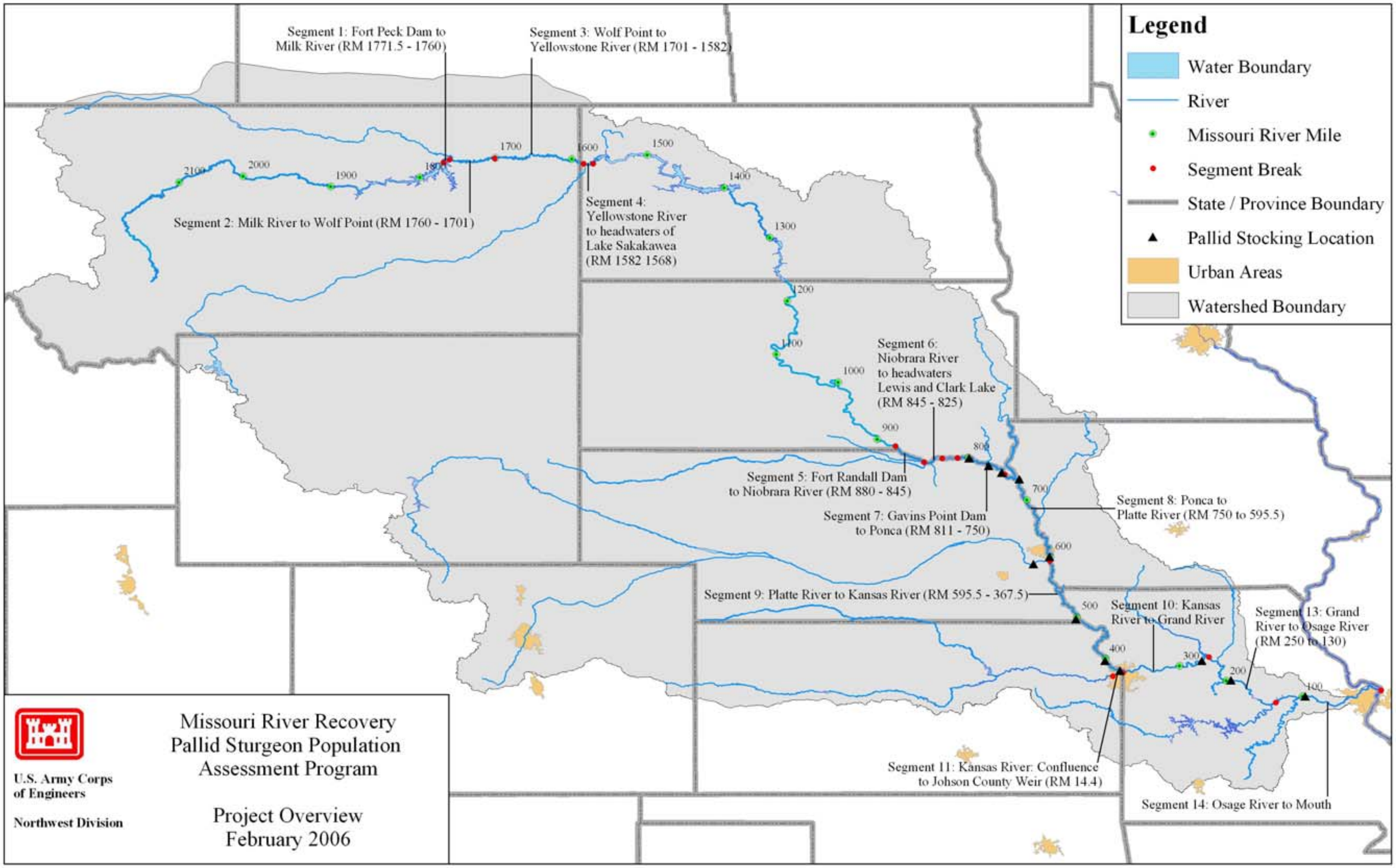

Figure 1. Map of the Missouri River basin.

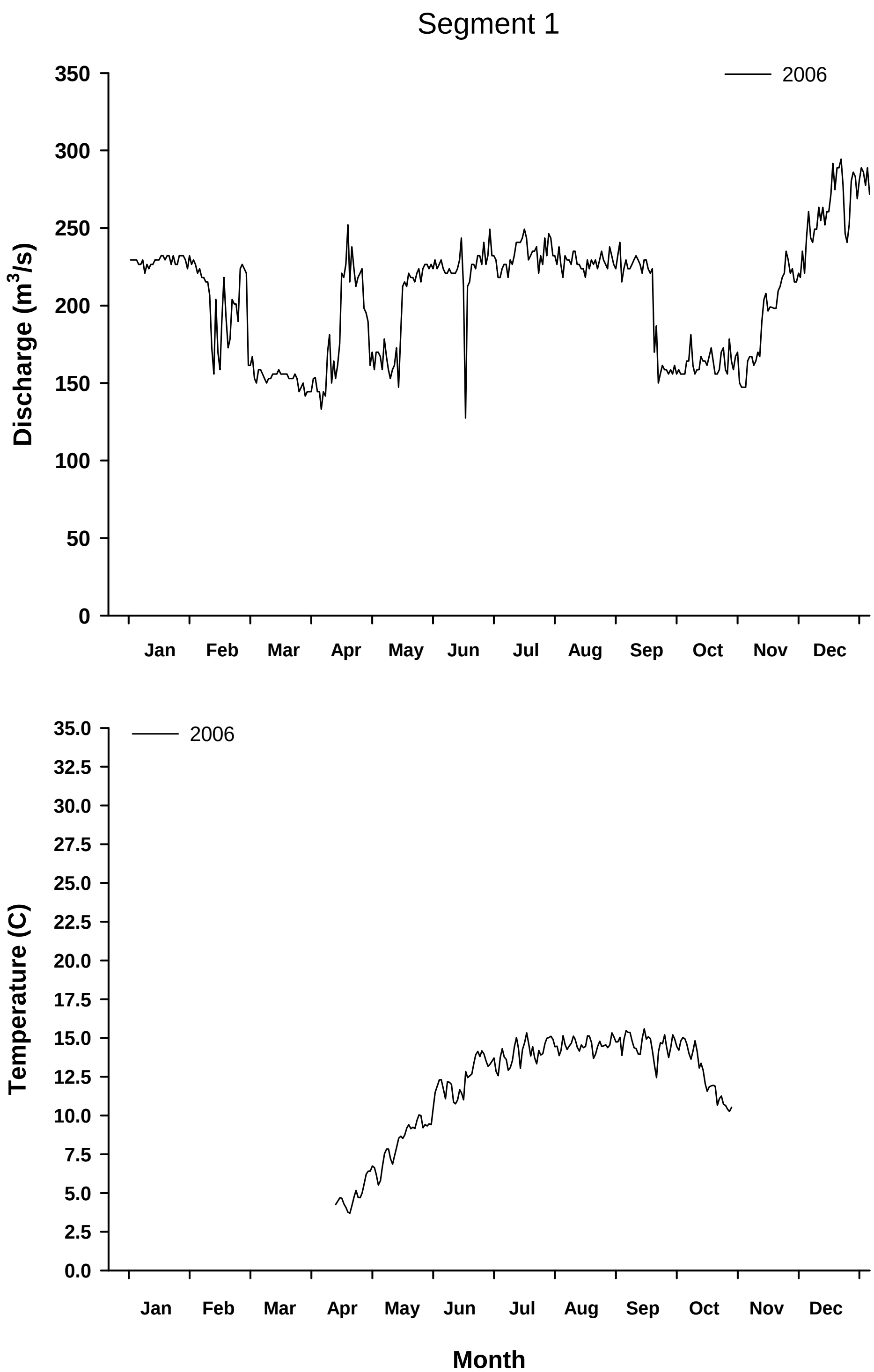

Figure 2. Mean daily discharge and mean daily water temperature for segment 1 of the Missouri River during 2006

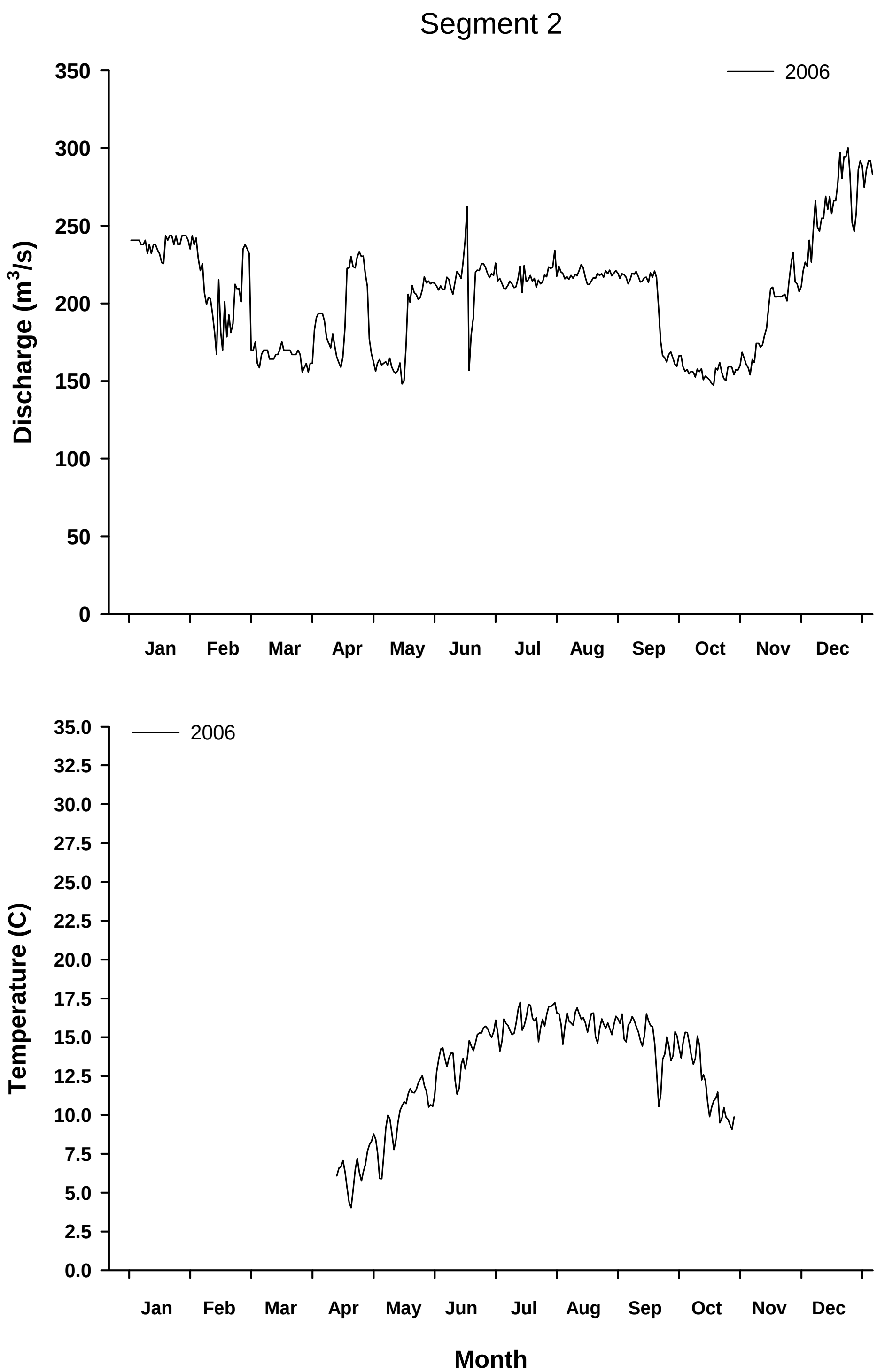

Figure 3. Mean daily discharge and mean daily water temperature for segment 2 of the Missouri River during 2006

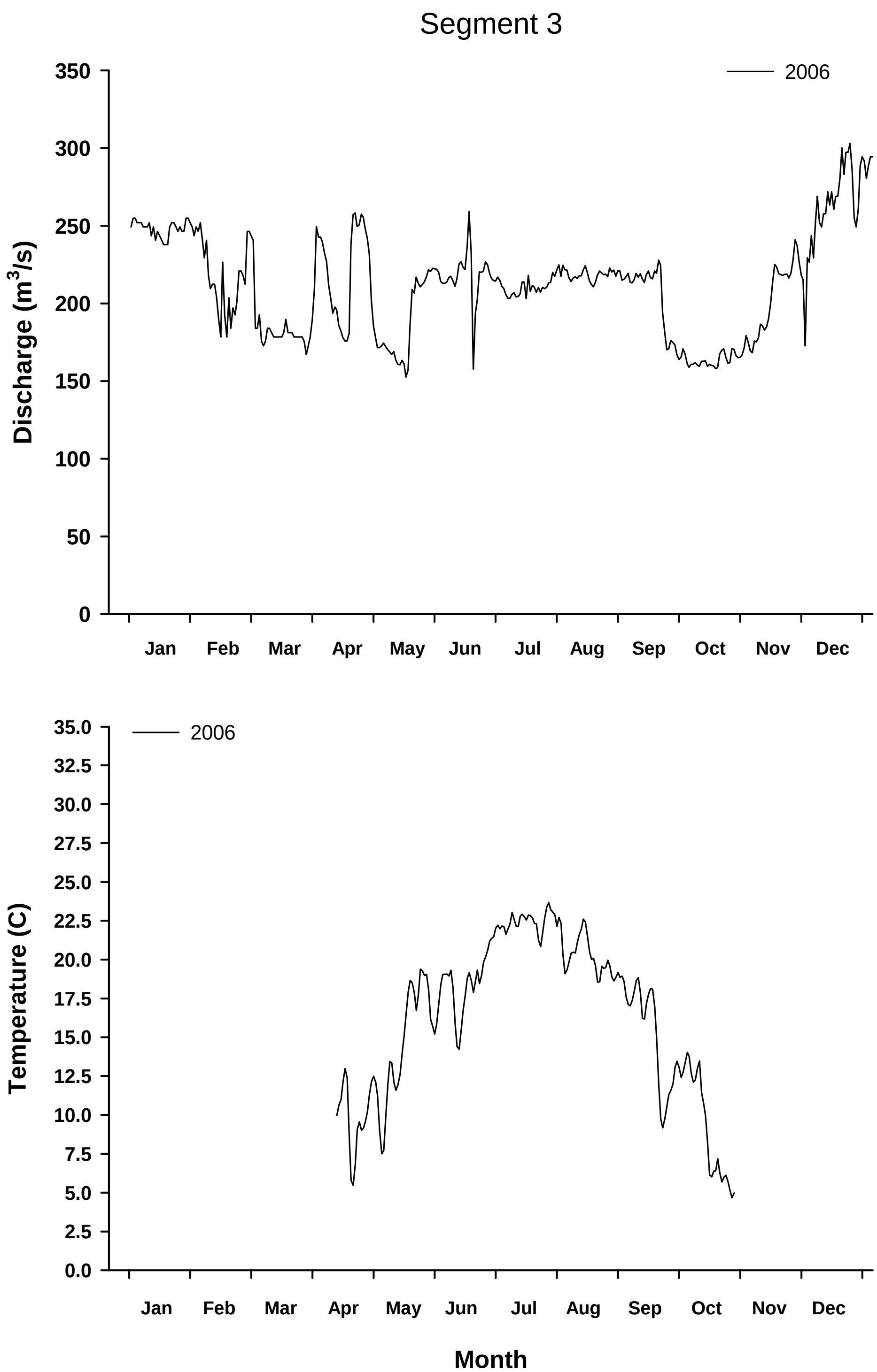

Figure 4. Mean daily discharge and mean daily water temperature for segment 3 of the Missouri River during 2006

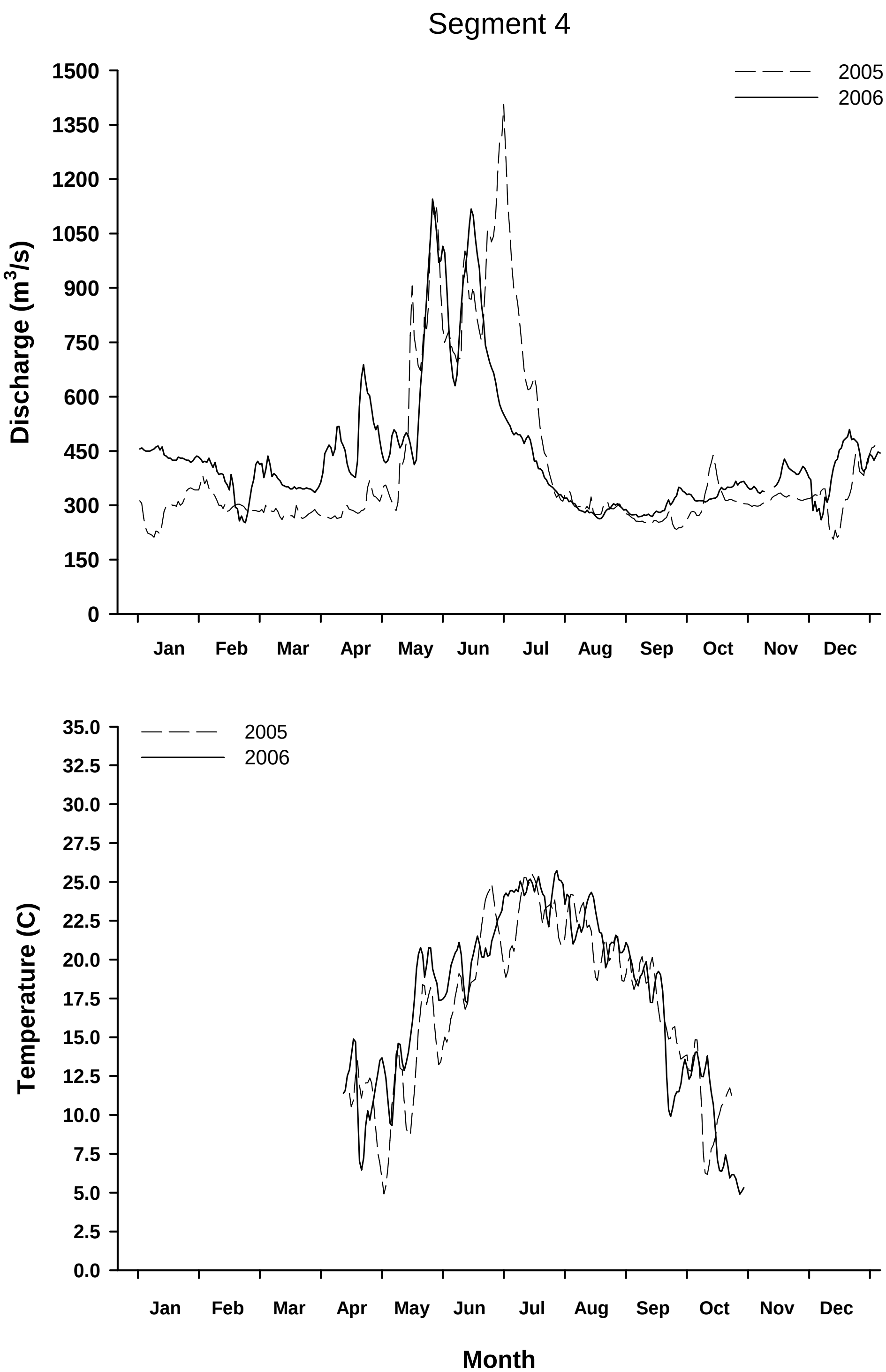

Figure 5. Mean daily discharge and mean daily water temperature for segment 4 of the Missouri River during 2005 and 2006.

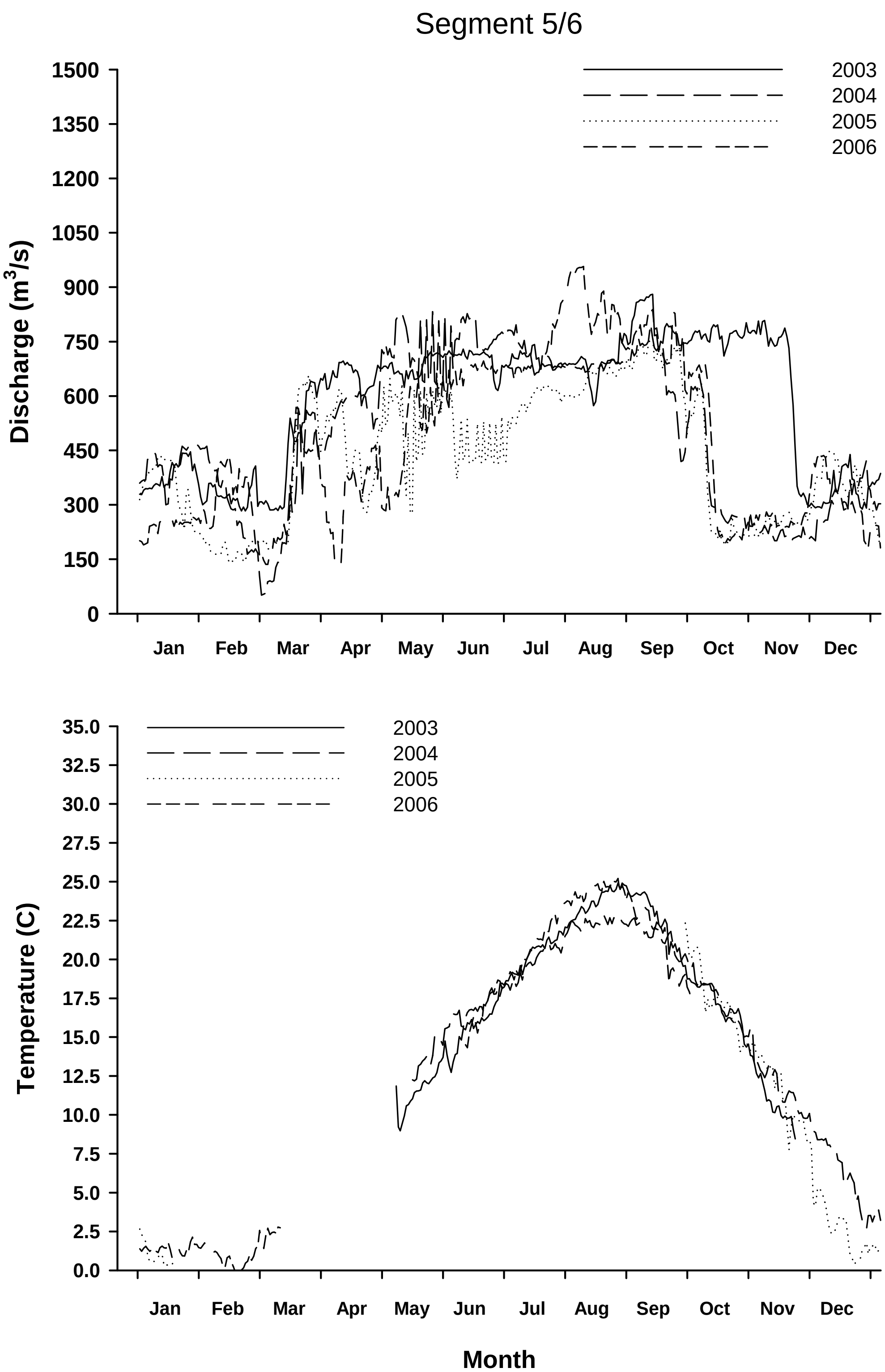

Figure 6. Mean daily discharge and mean daily water temperature for segment 5/6 of the Missouri River during 2003 through 2006.

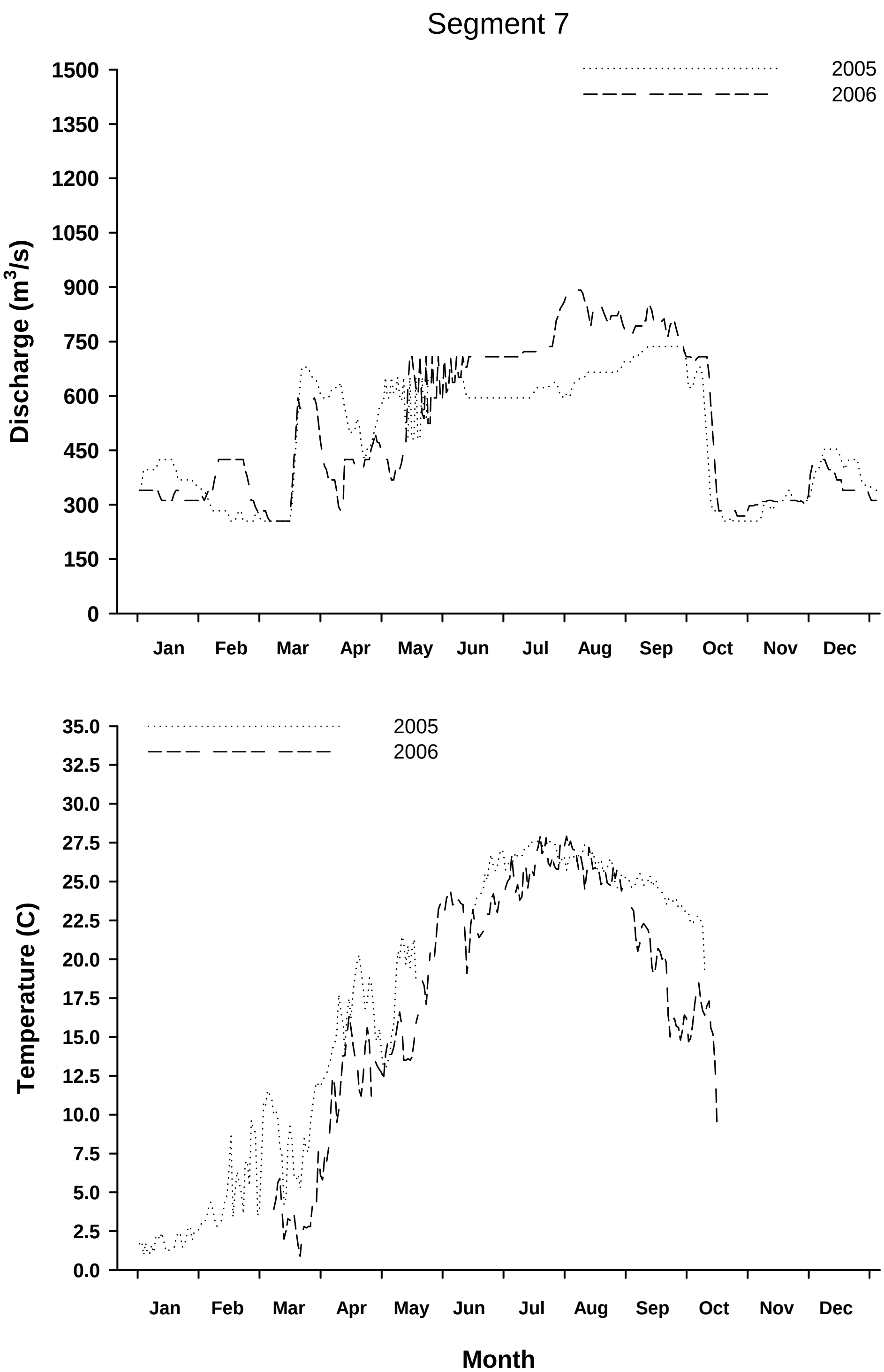

Figure 7. Mean daily discharge and mean daily water temperature for segment 7 of the Missouri River during 2005 and 2006.

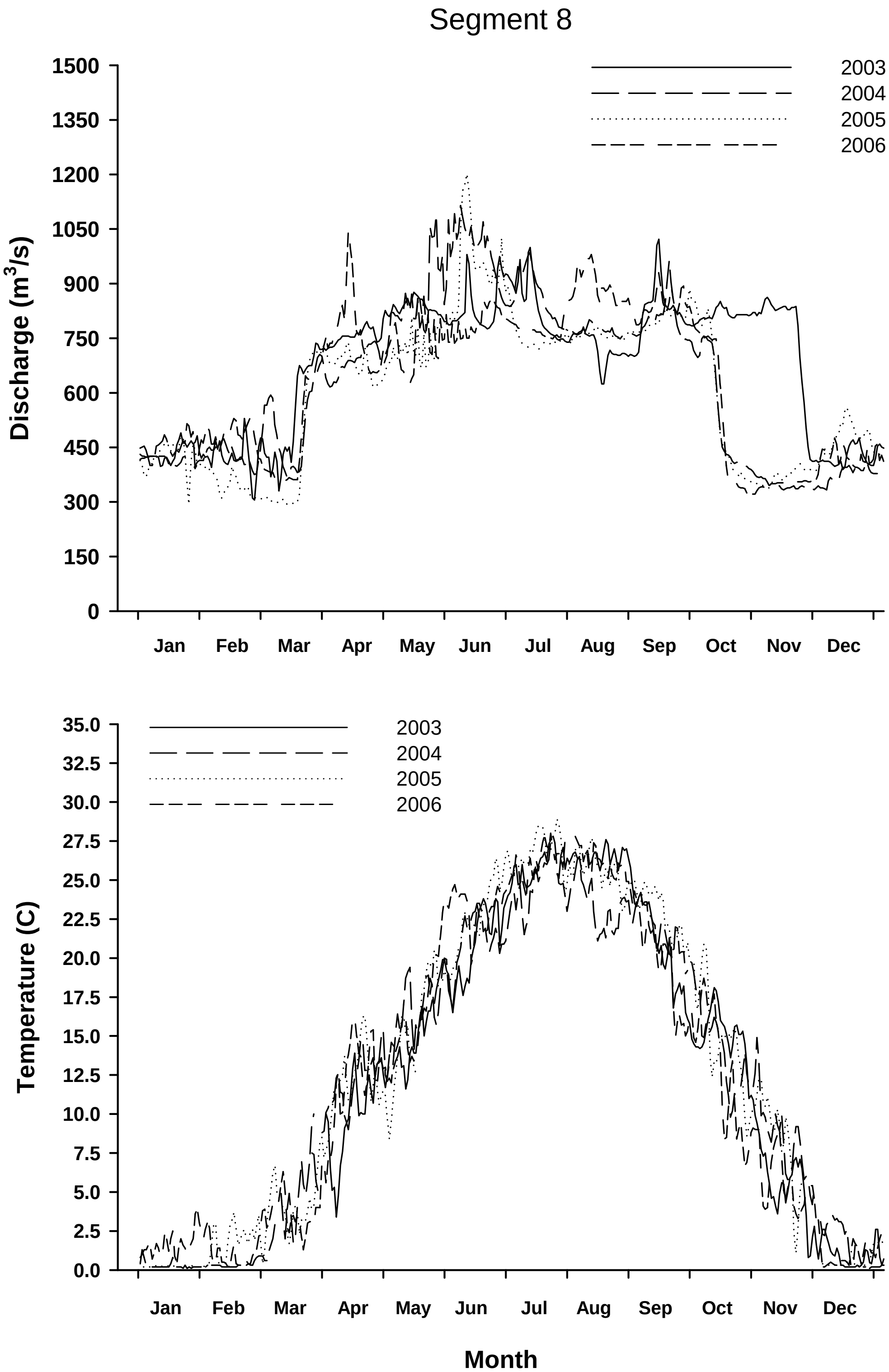

Figure 8. Mean daily discharge and mean daily water temperature for segment 8 of the Missouri River during 2003 through 2006.

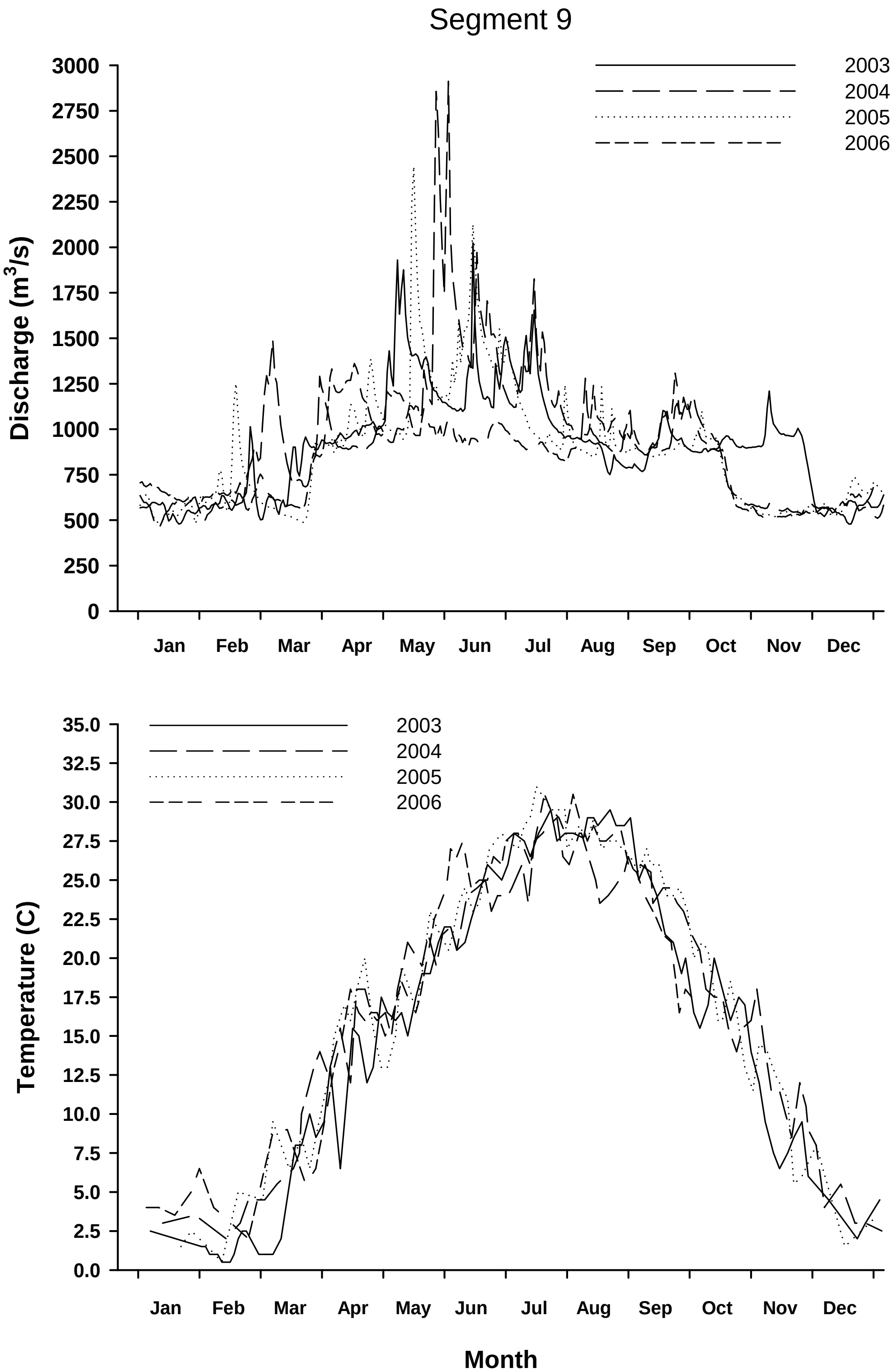

Figure 9. Mean daily discharge and mean daily water temperature for segment 9 of the Missouri River during 2003 through 2006.

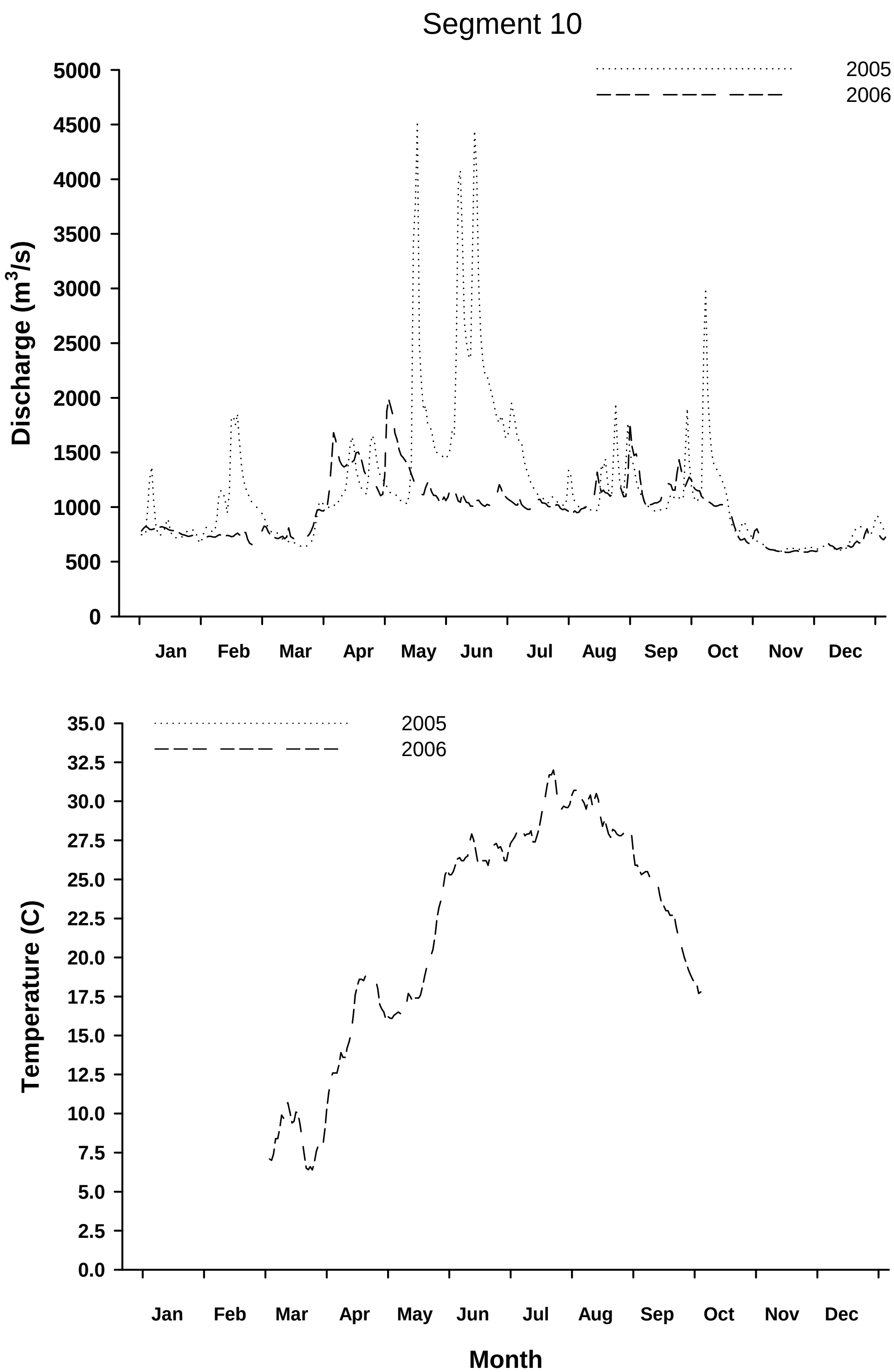

Figure 10. Mean daily discharge and mean daily water temperature for segment 10 of the Missouri River during 2005 and 2006.

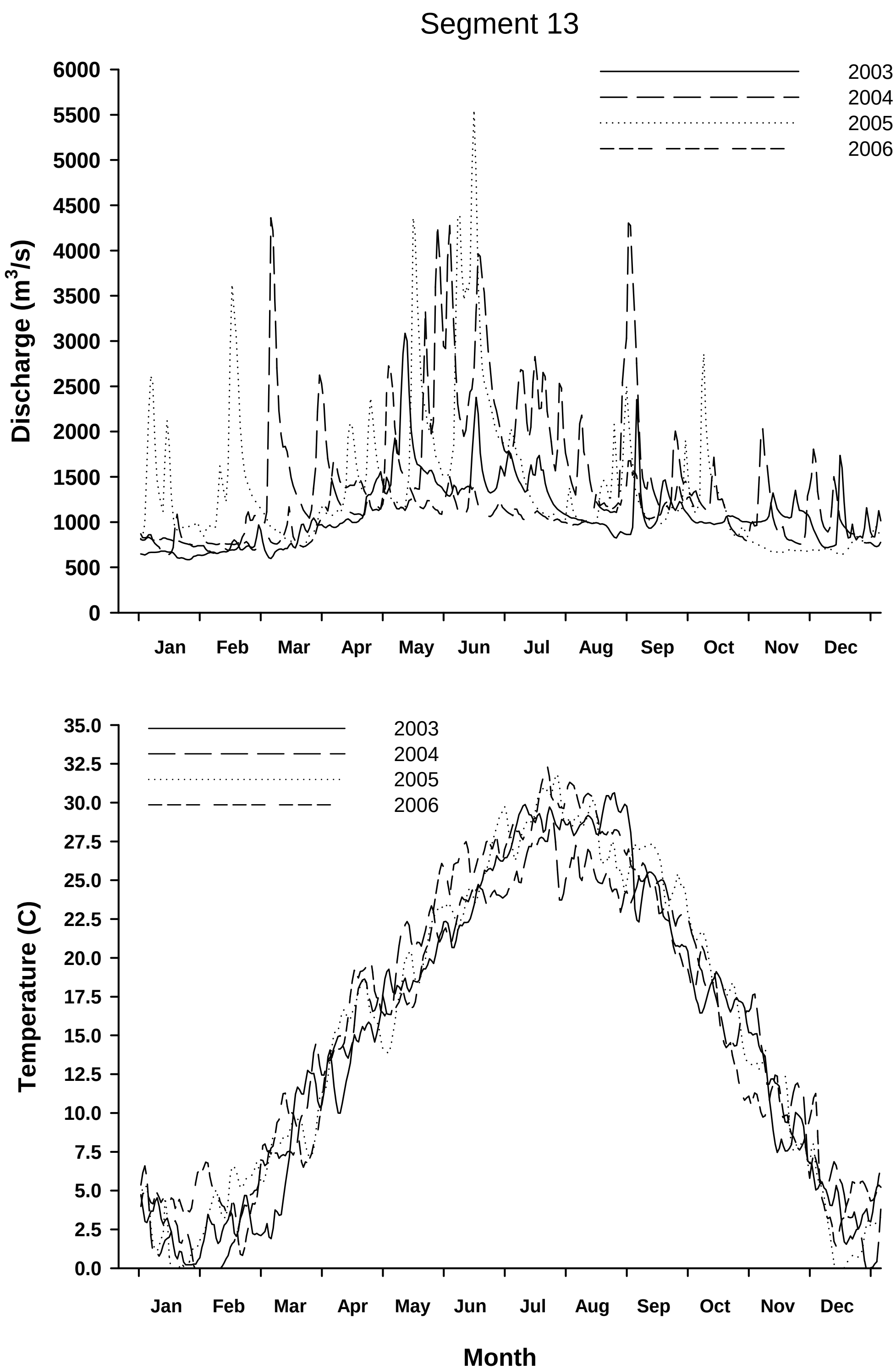

Figure 11. Mean daily discharge and mean daily water temperature for segment 13 of the Missouri River during 2003 through 2006.

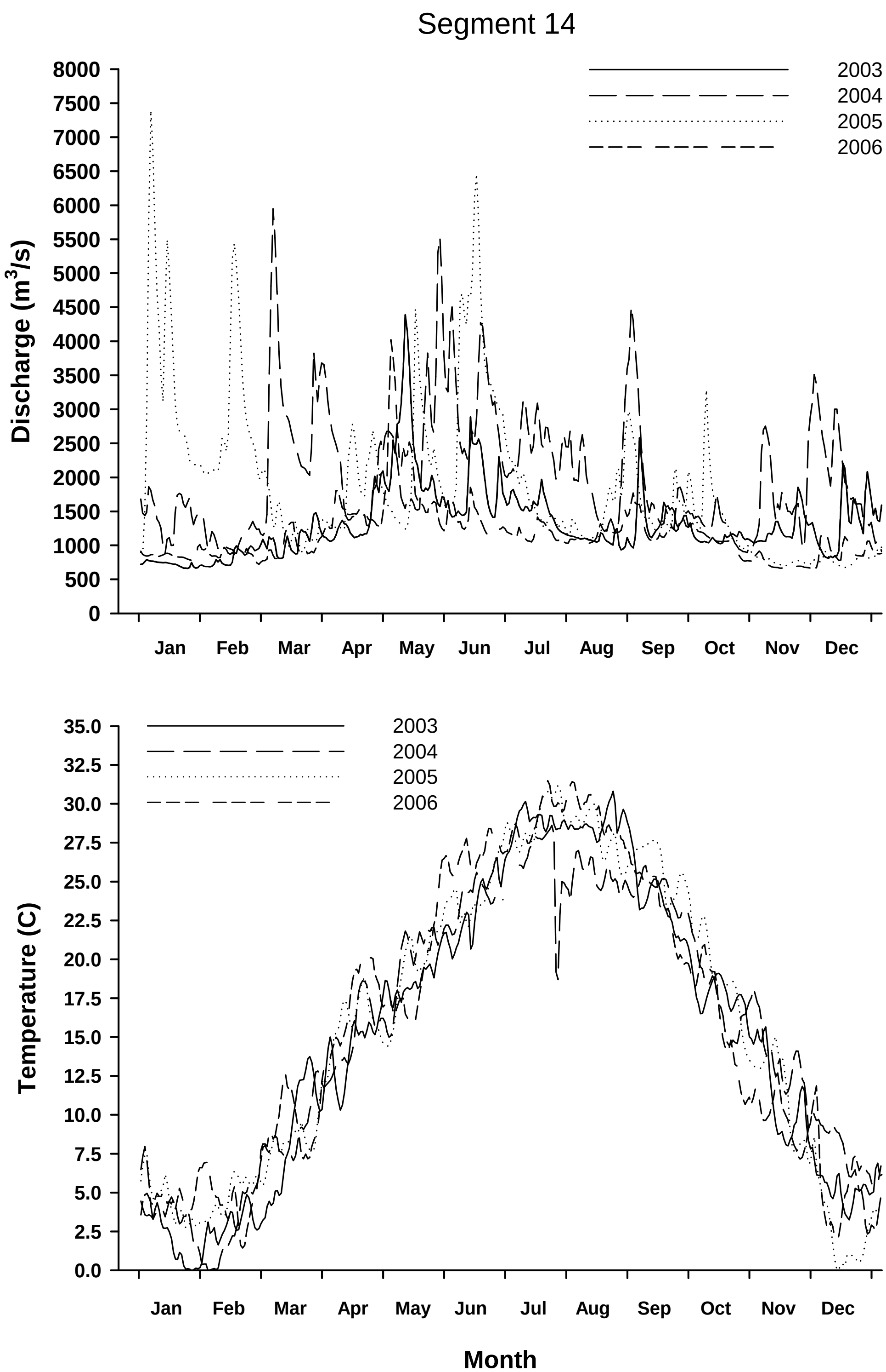

Figure 12. Mean daily discharge and mean daily water temperature for segment 14 of the Missouri River during 2003 through 2006.

Table 2. Specific dates for each year when aging structures of sand shiner were removed.

Year	Starting Date	Ending Date	Segments
2004	August 2004	September 2004	9
2005	July 2005	October 2005	7, 8, 9, 10 and 14
2006	July 2006	October 2006	2, 3, 7, 8, 9, 10,11, 13 and 14

Results

During 2004, 2005, and 2006, 5,116 sand shiners were captured in all river segments (Appendix B), aging structures were collected from 390 of these fish (Table 3). Mean back calculated length at age 1 for 2005 was 36 mm from segment 9 (Table 6). Mean back calculated lengths at age for 2006 were 32 mm and 49 mm at age 1 and 2, respectively (Table 7; Figure 16).

Sand shiner data were tested for normality using a Kurtosis test. A parametric ANOVA with a Tukey post-hoc test showed that during 2005 mean length at capture for age 0 fish in segment 7 was significantly larger than those from segments 8 and 10 (Table 10). During 2005 mean length at age 1 in segment 1 was significantly larger than that observed in segments 9 and 10 (Table 10), and mean length at age 1 in segment 8 was significantly larger than that observed in segments 10 (Table 10). No differences in mean length at ages 0 or 1 were observed among any of trhe segments during 2006 (Table 11). No differences were observed between the upper and lower universe for mean length at ages 0 and 1 (Table 12).

Length frequencies were compared among segments for each year resulting in no noticeable peaks in age classes. Length frequency graphs were then created for each month during fish community season for all years combined (Appendix D). Taylor and Miller (1990) employed this method with *Hybognathas spp*. to accurately age a population using length frequencies. The length frequency graphs for July-October graphs only showed two age class peaks.

Age frequencies were compared among segments for each year. Age frequencies for 2004 were 97% and 3% for age 0 and age 1 fish, respectively. Age frequencies for 2005 were 83% and 17% for age 0 and age 1, respectively. Age frequencies for 2006 were 80%, 19%, and 1% at age 0, 1, and 2, respectively (Appendix E).

Table 3. Total number of aging structures collected for age and growth analysis.

Length	Total	2004	2005					2006								
		9	**7**	**8**	**9**	**10**	**14**	**2**	**3**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
10	0															
20	38	10		10	2	2		1	3		4	5		1		
30	138	10	9	9	13	11	7	11	11	8	9	8	10	10	5	7
40	119	10	9	10	14	10	8	7	3	9	9	9	8	4	4	5
50	85	2	15	10	5	6	9	8	11	3	8	4			3	1
60	10		6	2	1				1							
70	0															
80																
90																
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250																
260																
270																
280																
290																
300																
310																

Table 4. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sand shiners collected in each segment during 2003. A mean total length-at-age of all segments combined is also provided for each age class.

Age	**Segments**												**Mean**
	1	**2**	**3**	**4**	**5 & 6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	
1													
2						No data for 2003							
3													
4													
5													
6													
7													
8													
9													
10													

Table 5. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sand shiners collected in each segment during 2004. A mean total length-at-age is not applicable because structures were only collected in segment 9 during 2004.

Age	Segments												Mean
	1	2	3	4	5 & 6	7	8	9	10	11	13	14	
1								33 (00.0)					
2													
3													
4													
5													
6													
7													
8													
9													
10													

Table 6. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sand shiners collected in each segment during 2005. A mean total length-at-age of all segments combined is also provided for each age class.

Age	**Segments**												**Mean**
	1	**2**	**3**	**4**	**5 & 6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	
1						39 (1.07)	35 (0.70)	32 (0.94)	32 (1.20)			31 (0.46)	36 (1.62)
2													
3													
4													
5													
6													
7													
8													
9													
10													

Table 7. Mean back-calculated total length-at-last annulus (+/- 2 SE) of sand shiners collected in each segment during 2006. A mean total length-at-age of all segments combined is also provided for each age class.

Age	**Segments**												**Mean**
	1	**2**	**3**	**4**	**5 & 6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	
1		35 (1.06)	35 (2.79)			26 (1.97)	31 (1.42)	35 (0.48)	31 (1.87)		36 (0.70)	32 (0.66)	32 (2.50)
2								49 (0.00)					49 (0.00)
3													
4													
5													
6													
7													
8													
9													
10													

Figure 13. No data for 2003.

Figure 14. Insufficient data for 2004.

Figure 15. Insufficient data for 2005.

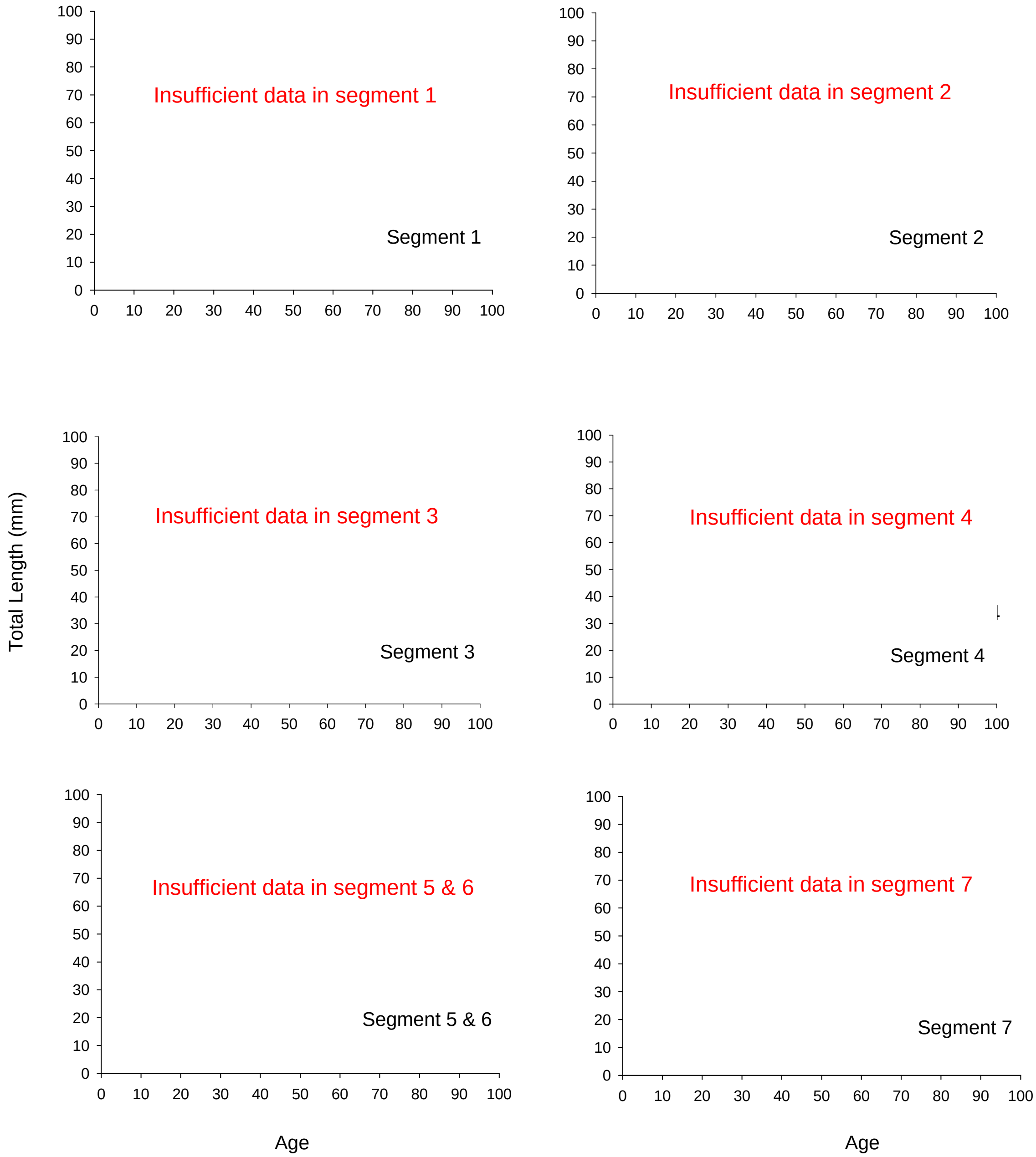

Figure 16. Mean back-calculated total length-at-last annulus curves of sand shiners that were collected for age and growth analysis from segments 1, 2, 3, 4, 5 & 6, 7, 8, 9, 10, 11, 13, and 14 of the Missouri River during 2006.

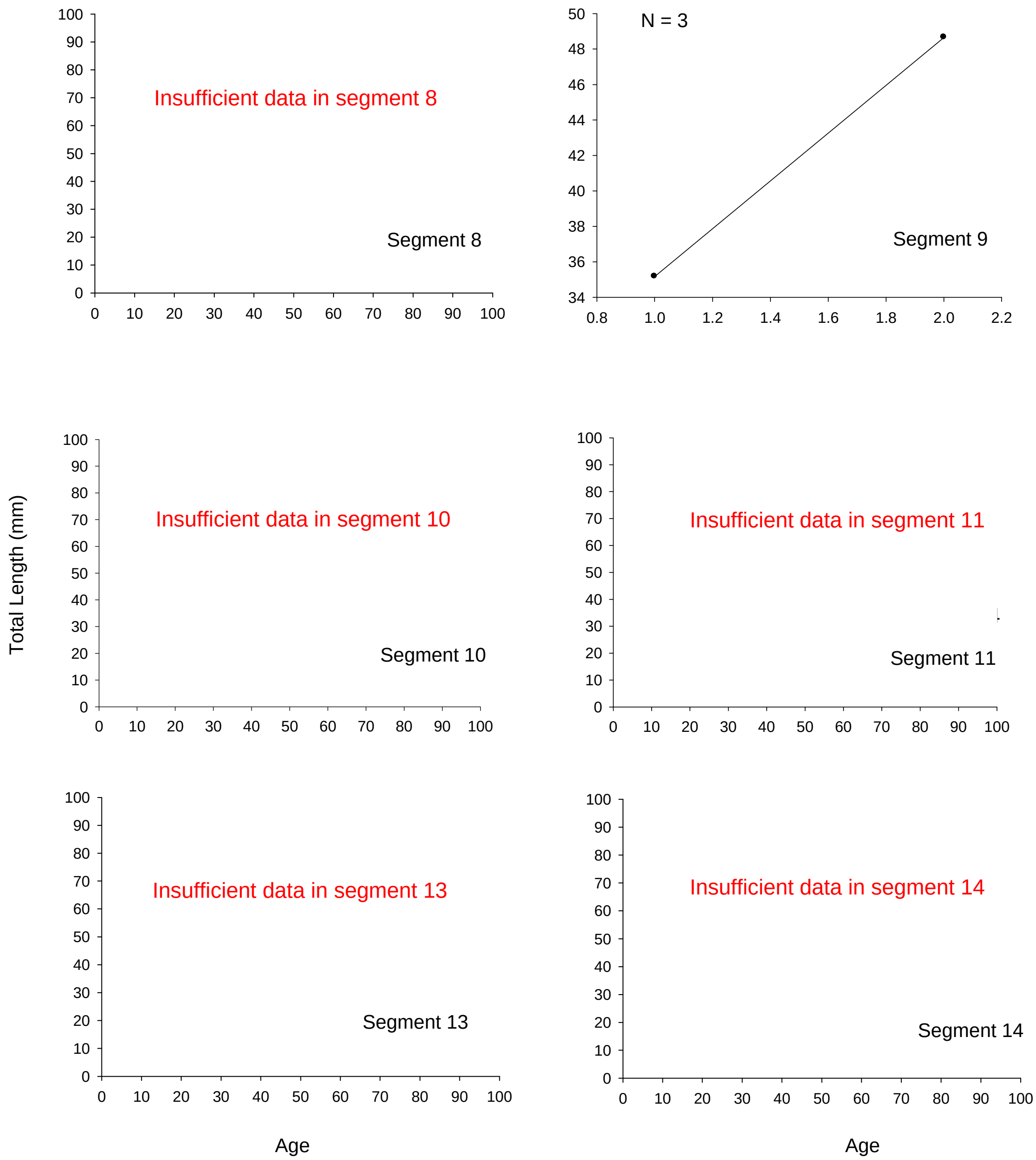

Figure 16. Continued.

Figure 17. Insufficient data for all years combined.

Figure 18. Insufficient data for universe comparison.

Table 8. Mean length-at-capture comparisons of sand shiners between segments for 2003. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0												
1												
2						No data for 2003						
3												
4												
5												
6												
7												
8												

Table 9. Mean length-at-capture comparisons of sand shiners between segments for 2004. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0												
1												
2												
3												
4												
5												
6												
7												
8												

Insufficient data for 2004

Table 10. Mean length-at-capture comparisons of sand shiners between segments for 2005. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0*						46 a (3.7, 26)	40 b (3.8, 36)	41 ab (2.9, 31)	40 b (3.0, 25)			45 ab (3.1, 22)
1*						55 a (2.3, 13)	54 ab (2.6, 5)	48 bc (2.5, 4)	46 c (6.9, 4)			52 abc (5.9, 2)
2												
3												
4												
5												
6												
7												
8												

Table 11. Mean length-at-capture comparisons of sand shiners between segments for 2006. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Segment comparisons were analyzed with a one-way ANOVA. Segments sharing a letter indicate no significant differences while different letters indicate significance differences (Tukey's test, alpha = 0.10).

	Segment											
Age	**1**	**2**	**3**	**4**	**5/6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**
0*		42 a (3.8, 25)	40 a (4.1, 23)			39 a (1.6, 14)	38 a (4.1, 20)	37 a (3.2, 23)	38 a (1.5, 15)	37 a (2.0, 15)	42 a (3.7, 9)	39 a (1.8, 9)
1*		49 a (1.0, 2)	53 a (3.1, 6)			48 a (4.4, 6)	48 a (3.6, 10)	55 a (3.9, 2)	47 a (2.4, 3)		47 a (3.4, 3)	45 a (7.8, 4)
2								55 (-, 1)				
3												
4												
5												
6												
7												
8												

Table 12. Mean length-at-capture comparisons of sand shiners between the upper and lower sampling universe. Numbers below mean lengths are (+/-) 95% confidence interval and sample size, respectively. Dashes (-) indicate insufficient data to calculate confidence interval. Asterisks (*) indicate ages tested for significant differences among segments. Sampling universe comparisons were analyzed with a t-test. Sharing a letter indicate no significant differences while different letters indicate significance differences (alpha = 0.05).

Age	**Sampling Universe**	
	Upper	**Lower**
0*	41 a (2.8, 48)	40 a (1.0, 276)
1*	52 a (2.7, 8)	50 a (1.5, 57)
2		55 (-, 1)
3		
4		
5		
6		
7		
8		

Table 13. Age/length key for segment 1. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20				
25				
30				
35				
40	No data for segment 1			
45				
50				
55				
60				

Table 14. Age/length key for segment 2. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	**Age**			
	0	**1**	**2**	**N**
20				
25	100			1
30	100			7
35	100			4
40	100			2
45	60	40		5
50	100			6
55	100			2
60				

Table 15. Age/length key for segment 3. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	**Age**			**N**
	0	**1**	**2**	
20				
25	100			3
30	100			4
35	100			7
40	100			1
45	50	50		2
50	57	43		7
55	75	25		4
60		100		1

Table 16. Age/length key for segment 4. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20				
25				
30				
35				
40	No data for segment 4			
45				
50				
55				
60				

Table 17. Age/length key for segments 5 and 6. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20				
25				
30				
35				
40	No data for segment 5 & 6			
45				
50				
55				
60				

Table 18. Age/length key for segment 7. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	**Age**			
	0	**1**	**2**	**N**
20				
25				
30	100			6
35	91	9		11
40	89	11		9
45	67	33		9
50	33	67		9
55	44	56		9
60	50	50		6

Table 19. Age/length key for segment 8. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20	100			2
25	100			12
30	100			8
35	100			10
40	60	40		10
45	89	11		9
50	40	60		10
55	50	50		8
60	100			2

Table 20. Age/length key for segment 9. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20				
25	100			17
30	100			14
35	100			17
40	100			22
45	73	27		11
50	63	38		8
55	33	33	33	2
60	100			1

Table 21. Age/length key for segment 10. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	**Age**			**N**
	0	**1**	**2**	
20				
25	100			2
30	100			7
35	93	7		14
40	100			11
45	29	71		7
50	83	17		6
55				
60				

Table 22. Age/length key for segment 11. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20				
25	100			1
30	100			1
35	100			9
40	100			4
45				
50				
55				
60				

Table 23. Age/length key for segment 13. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	1	2	N
20				
25				
30				
35	100			5
40	67	33		3
45	67	33		3
50	75	25		4
55				
60				

Table 24. Age/length key for segment 14. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data from each segment.

Length Category	Age 0	Age 1	Age 2	N
20				
25				
30	100			2
35	92	8		12
40	88	13		8
45	60	40		5
50	100			6
55	50	50		4
60				

Additional Analysis

There was not sufficient data to accurately assign an age to fish using the age/length keys based on segment (Tables 13-24). Therefore, data from each segments were combined to make an age length key for the upper (Appendix F) and lower (Appendix G) sampling universe to assign an age to all sand shiners sampled. Annual mortality was compared among segments for all years combined. Fish in the upper universe had an annual mortality rate of 95%, while fish in the lower universe had an annual mortality rate of 85% (Appendix H).

Structure age estimations were obtained independently by two readers. Reader agreement was tested to determine the accuracy and precision of our results. Exact reader agreement was 92% for sand shiners. The rate of reader agreement within +/-1 year was 100%.

Discussion

Length frequency graphs of sand shiners showed three age classes for all 4 months (Appendix D). The number captured decreased during the month of October. This could be the result of a reduction in the use of sampling gears targeting small-bodies species during this time period. Taylor and Miller (1990) used length frequency histograms to analyze age and growth data of *Hybognathus placitus* because annuli on scales could not be identified. A comparison of data from our age and growth analysis to monthly length-frequency graphs showed similar age classes. Taking into account the accuracy of length frequencies to represent the age of this species and the time invested in preparation and reading scales, we feel sand shiners could be accurately and more efficiently aged using length-frequency histograms.

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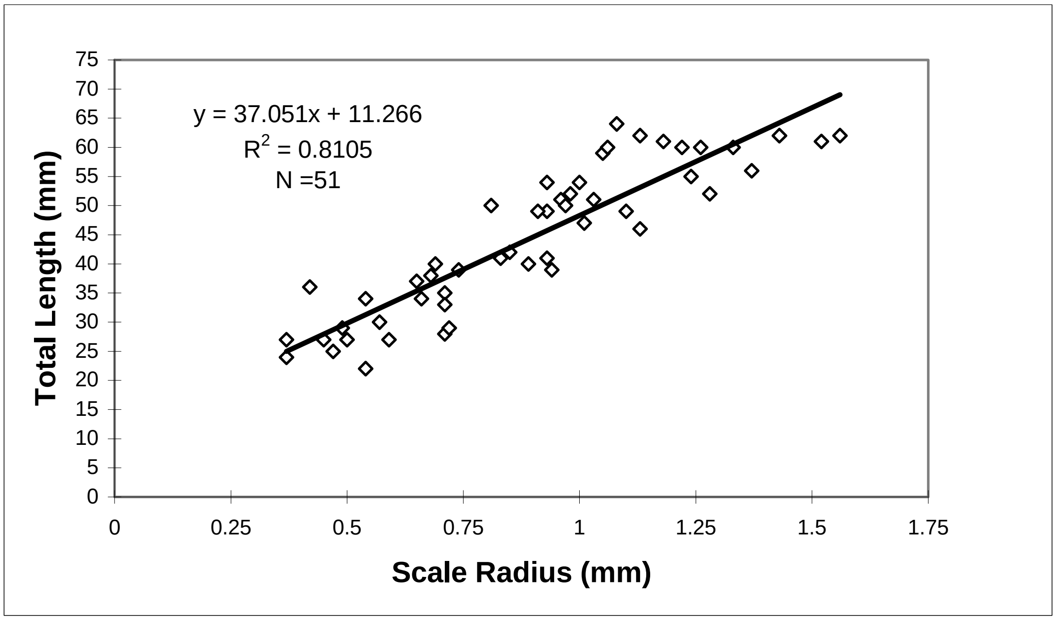
Appendices

Appendix A. Linear regression used to calculate Y-intercept for sand shiners.

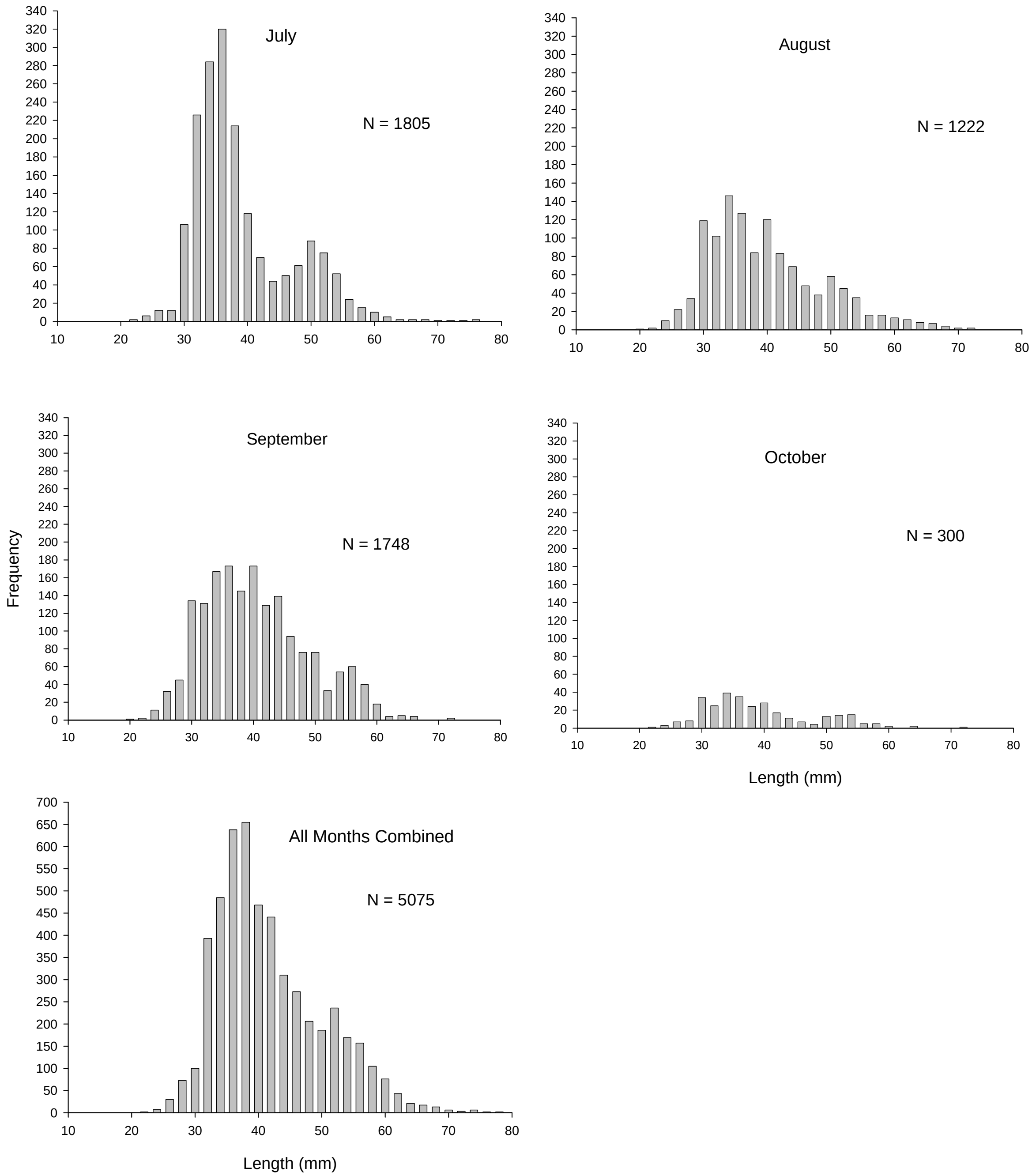


Appendix B. Total number of sand shiners sampled in the Missouri River for each segment during 2004, 2005, and 2006.

	2004	2005	2006	Totals
Segment 1			1	1
Segment 2			195	195
Segment 3			584	584
Segment 4		1	7	8
Segments 5 & 6	218	26	43	287
Segment 7		1076	352	1428
Segment 8		252	888	1140
Segment 9	160	154	757	1071
Segment 10		62	54	116
Segment 11			91	91
Segment 13	14	3	40	57
Segment 14		86	52	138
Totals	392	1660	3064	**5116**

Appendix C. Length-at-capture and back-calculated length comparisons between the upper and lower sampling universe for sand shiners for all years combined.

Age	Mean total length at capture		Mean back calculated total length	
	Upper	Lower	Upper	Lower
0	41	40	-	-
1	52	50	35	33
2		55		49
3				



Appendix D. Length Frequency of sand shiners collected from the Missouri River month during each of fish community season and all months combined from 2004 - 2006.

Appendix E. Age frequency tables for sand shiners that were collected for age and growth analysis for each segment of the Missouri River during 2004, 2005, and 2006.

2004				
Segment	Age			
	0	1	2	3
9	31	1		
Total	31	1	0	0
Percentage	97%	3%	-	-

2005				
Segment	Age			
	0	1	2	3
7	26	13		
8	36	5		
9	31	4		
10	25	4		
14	22	2		
Total	140	28	0	0
Percentage	83%	17%	-	-

2006				
Segment	Age			
	0	1	2	3
2	25	2		
3	23	6		
7	14	6		
8	20	10		
9	23	2	1	
10	15	3		
11	15			
13	9	3		
14	9	4		
Total	153	36	1	0
Percentage	80%	19%	1%	-

Appendix F. Age/length key for the upper universe. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data.

Length Category	**Age**			**N**
	0	**1**	**2**	
20				
25	100			4
30	100			11
35	100			11
40	100			3
45	57	43		7
50	77	23		13
55	83	17		6
60		100		1

Appendix G. Age/length key for lower universe. Numbers in the boxes represent the probability that a known length individual is a certain age based on raw aging data.

Length Category	**Age**			**N**
	0	**1**	**2**	
20	100			2
25	100			32
30	100			38
35	96	4		78
40	90	10		67
45	66	34		44
50	60	40		43
55	46	50	4	24
60	67	33		9

Appendix H. Sand shiner annual mortality rate using Heincke's method for each segment of the Missouri River for all years combined.

Segment Number	Annual Mortality
2	90%
3	97%
4	63%
5 & 6	62%
7	82%
8	88%
9	92%
10	91%
11	92%
13	88%
14	79%
Upper Universe	95%
Lower Universe	85%